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# Comparing the risk profiles of renewable and natural gas-fired electricity contracts

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**Abstract**

Electricity policymakers, industry participants, analysts, and even consumers have become acutely aware of the ever-present risks that face the delivery of electricity. Recent instability in the electricity industry illustrates the need for thoughtful resource planning to balance the cost, reliability, and risk of electricity supply. This article evaluates the relative risk profiles of renewable and natural gas generating plants. It does so by analyzing how six different risks are allocated and, if possible, mitigated in long-term power purchase contracts, taking as a contract sample 27 agreements signed by the California Department of Water Resources in 2001. This assessment illustrates some of the significant differences between the risk profiles of natural gas-fired and renewable generation. Renewable energy contracts are shown to provide the most value relative to natural gas-fired contracts by mitigating fuel price and environmental compliance risks. Gas-fired electricity contracts typically provide better protection against short-term demand risk. When it comes to fuel supply, performance, and regulatory risks, the relative value of renewable and gas-fired contracts is ambiguous. We conclude that a better understanding of risks and risk allocation practices will help utilities, regulators, and others make more objective decisions in the future when selecting between renewable and gas-fired electricity supply.


*Keywords:* Risk; Uncertainty; Renewable energy; Natural gas; Electricity contracts

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## 1. Introduction

Electricity markets in the United States have witnessed unprecedented instability over the last few years, with substantial volatility in wholesale market prices, significant financial distress among major energy suppliers, and unprecedented legal, regulatory and legislative activity. These events demonstrate the considerable risks that exist in the electricity industry. Recent industry instability also illustrates the need for thoughtful resource planning to balance the cost, reliability, and risk of

the electricity supplied to end-use customers. In balancing different supply options, utilities, regulators, and other resource planners must consider the unique risk profiles of each generating source [1].

The risks that exist in the electricity industry depend in part on the technologies that are used to generate electricity. Natural gas has become the fuel of choice for new power plant additions in the US and elsewhere. To some, this emphasis on a single fuel source signals the potential for increased risk, especially because the underlying cost of natural gas has exhibited considerable variability. Although not yet widely utilized, renewable energy resources such as wind, biomass, geothermal, hydropower, and solar energy are receiving increasing consideration. Though historically supported through direct public policy measures, the costs of renewable energy technologies have declined, making it possible in some circumstances to make the case for renewable energy based on cost alone. Of particular importance to this paper, renewable generation sources are frequently cited as a potent source of socially beneficial risk reduction relative to natural gas-fired generation [2,3]. And yet, renewable generation imposes new and different risks on the electricity system.

This paper evaluates the relative risk profiles of renewable and natural gas generating plants. It does so by comparing the allocation and, if possible, mitigation of risks in long-term natural gas-fired electricity contracts with the treatment of these same risks in long-term renewable energy contracts. This comparison highlights some of the key risk-related differences between renewable and natural gas generation that decision makers should consider when making electricity investment and contracting decisions.

Our assessment is relevant in both regulated and restructured electricity markets. In still-regulated markets, the audience for this article clearly includes regulators and the utilities they regulate. In restructured markets, the role of regulatory oversight of resource planning is more limited. Nonetheless, even in restructured markets, it is increasingly recognized that regulators have a critical role to play in directing the resource planning of providers of last resort—electric suppliers that provide service to those customers who choose not to switch to a competitive supplier. Our review of electricity contracts may also have educational value for those unfamiliar with the typical contents of such agreements.

We begin this article by defining our use of the term "risk", briefly describing terms and distinctions that we use throughout the paper, and outlining the specific risks that we analyze in our contract sample. We then review the contract sample used for our evaluation, specifically, 20 conventional (primarily natural gas) contracts and seven renewable energy contracts signed by the California Department of Water Resources (DWR) in 2001. The remaining sections of the article examine how the DWR's long-term natural gas and renewable generation contracts allocate and, if possible, mitigate various risks: (1) fuel price and fuel supply risk, (2) demand risk, (3) performance risk, (4) environmental compliance risk, and (5) other regulatory risks. The final section offers some brief conclusions.[1]

[1] This article is based on a longer Berkeley Lab report by Bachrach et al. [4].

## 2. Risks in electricity contracts: background concepts

### 2.1. An introduction to risk

The term "risk" in everyday life is generally used to refer to the potential for future harm. In a more formal and academic sense, however, risk simply refers to a future that is uncertain, independent of whether the future outcome will be beneficial or detrimental.[2] Here we adopt this more formal definition of risk.

It is plausible to think that society would wish to reduce the risk, or uncertainty, of electricity supply and cost. After all, it is ordinarily assumed that most people, and that society as a whole, are risk averse. Most people therefore place a value on being able to predict a future outcome with certainty, and they are often willing to pay to eliminate future risk.

### 2.2. Risk categorization

Long-term electricity contracts seek to allocate and manage a variety of different types of risk. In our review of the DWR's long-term electricity contracts, we focus on some of the most important risk allocation provisions, including:[3]

- *Fuel price risk*. The risk that the price of the fuel used to generate electricity will exhibit variability, resulting in an uncertain cost to generate electricity.
- *Fuel supply risk*. The risk that the fuel supply to a power plant will be unreliable, resulting in the inability to generate electricity in a predictable and dependable manner.
- *Demand risk*. The risk that the electricity that has been contracted for will not be needed as anticipated, or that there will not be enough electricity to meet fluctuating demand.
- *Performance risk*. The risk that the generator may not be willing or able to deliver electricity according to contractually prescribed requirements in terms of time and quantity.
- *Environmental compliance risk*. The financial risk to which parties to an electricity contract are exposed, stemming from both existing environmental regulations and the uncertainty over possible future regulations.

[2] In academic circles, the states of incertitude about the future are sometimes distinguished using three different concepts: risk, uncertainty, and ignorance. Risk analysis attempts to model the future by specifying probabilities for a complete set of possible outcomes. Uncertainty is distinguished as a separate concept that is used when probabilities of outcomes are inestimable, but the complete set of possible outcomes is still known. The final concept is ignorance about the future. Ignorance exists when one is unable to assign probabilities to future outcomes, or even to specify the complete set of possible outcomes [5]. Our qualitative use of the term "risk" in this paper encompasses all three of the above-defined states of incertitude.

[3] We acknowledge a certain amount of overlap among these categories, for example, fuel supply, performance, and demand risks are all related. Environmental and regulatory risks are also related.

- *Regulatory risk*. The risk that future laws or regulations, or regulatory review or renegotiation of a contract, will alter the benefits or burdens of a contract to either party.

The parties to an electricity contract face numerous additional sources of uncertainty as well, including the risk that the transmission system will be unreliable and the risk that a party to the contract will default on its obligations. These risks are not addressed explicitly in this paper, but default risk in particular is addressed peripherally in our discussion of other risk elements.

### 2.3. Two important conceptual distinctions

In discussing risk, we make two conceptual distinctions that will be used in the pages that follow.

- *Risk allocation vs. risk mitigation*: There are two different actions that can be taken when a risk exists: the risk can be *allocated* among a group of parties, or the risk can be *mitigated* by one or more parties. The allocation of a risk determines who will bear the consequences of an uncertain future event. For example, the allocation of the risk of a future change in tax law determines who will pay for a tax increase or benefit from a tax decrease. Risk mitigation, on the other hand, reduces the uncertainty associated with a future event, or reduces the potential impact of the event. For example, in order to mitigate fuel price risk, a developer can choose to build a wind-powered generation facility (that requires no fuel) rather than a natural gas-fired power plant. As shown in the sections that follow, power purchase contracts principally address risk allocation, but the allocation of risks will have a direct influence on their mitigation.
- *Systematic risk vs. unsystematic risk*: Risks can either be unsystematic or systematic in nature. As defined here, an unsystematic risk affects an individual member of a group and is uncorrelated with the risk that the same event or outcome will affect other individuals. For example, the risk that one power plant will be poorly maintained may not affect the likelihood that another power plant will be maintained in a similarly poor manner. A systematic risk, on the other hand, is a risk that affects all members of a group simultaneously. For example, the risk that a major natural gas pipeline entering California might be crippled and interrupt fuel supply would affect many of the State's natural gas-fired power plants simultaneously. Though our terminology here differs from that found in finance textbooks, as a general rule, systematic risks are far more socially problematic than are unsystematic risks.[4]

[4] In finance textbooks, these terms refer to the ability to diversify risk away, and the correlation of certain events with stock market returns [6].

## 3. Overview of the contract sample

Power purchase agreements play a central role in allocating risks among parties in the electricity industry [7]. The extent of risk that any particular party bears depends in large part on how risks are allocated in these contracts. The allocation of risks in the electric industry, in turn, influences electricity investment decisions, and thereby has a significant impact on what types of power plants are built and the overall portfolio of electricity supply.[5] These long-term contracts are often held in confidence, however, with only the barest minimum of details released to the public. This has historically made a direct comparison of contract terms and risk allocation difficult.

Our contract sample consists of the original 27 long-term (3 years and longer) electricity contracts signed by the California Department of Water Resources in 2001 on behalf of the customers of California's three investor-owned utilities (IOU) during the California electricity crisis.[6] We performed a detailed review of these contracts, focusing on the financial and reliability risks as defined above from the perspectives of both parties to the contracts. We also reviewed several other analyses of the DWR contracts [9–12]. Subsequent to our review, a number of the DWR contracts were renegotiated or terminated. Many of these changes are favorable to the State, either reducing the cost of the power or the risks allocated to the purchaser. These renegotiated terms are *not* reflected in this paper.

The DWR contracts form the basis of our analysis for several reasons:[7]

- The DWR contracted with both natural gas and renewable power plants, allowing a comparison of risk profiles and allocation in the two classes of contracts.
- These agreements represent an unusually large sample of publicly available contracts, providing a unique opportunity to analyze the treatment of risk in electricity contracts.
- The DWR contracts will play an important role over the next decade in determining the shape of California's electricity industry—an industry that provides an essential input to one of the largest economies in the world.

It is useful, however, to understand the unique circumstances surrounding these contracts. In January 2001—during the height of the California electricity crisis—the credit ratings of California's major utilities were downgraded to junk status due to financial difficulties caused by extremely high wholesale market prices cou-

[5] This article does not include an analysis of various other contract types—such as financing and fuel supply agreements—and therefore does not represent a complete analysis of the allocation of risks. For an analysis of the allocation of risks in loan agreements, see Kahn et al. [8].

[6] Our sample does not include the DWR's shorter-term purchases because investments in new generating plants, whether renewable or natural gas, typically require long-term contracts.

[7] Although the DWR contracts have since been assigned to the investor-owned utilities, for simplicity, in this article, we state that the DWR bears costs or risks associated with the contracts rather than the utilities or their customers.

pled with frozen, regulated, retail rates. Generators were unwilling to continue selling electricity to the utilities, and during the ensuing two days of rolling blackouts, the State dove into the power purchasing business in order to keep the lights on in California. To fill the void for a creditworthy power purchaser, the State enlisted the DWR, and the DWR was soon purchasing one-third of the electricity used by the customers of California's three IOUs from the spot market [9]. Soon thereafter, the California legislature authorized the DWR to enter into long-term contracts in order to decrease the State's exposure to the volatile and expensive spot market. It is from this large and unprecedented power contracting effort that the DWR contracts were born.

The unique conditions surrounding the DWR contracting process surely yielded contracts that were executed in a hurry and are more favorable to the generators ("Sellers") than would have been the case were the contracts signed in more normal times [9,10]. The average price of the DWR contracts is also now very clearly higher than the "norm". Despite these circumstances, however, we believe that the terms and conditions embedded in the contracts do provide insight into the risk allocation and mitigation practices common in the electric industry. This results, in part, from the DWR's use of industry-standard contract templates.[8] Additionally, both the Sellers and the DWR had strong incentive to enter into mutually agreeable contracts, and all parties to the contracts employed experienced negotiators. Issues associated with whether the DWR contracts are "representative" are treated more systematically in Bachrach et al. [4].

The DWR's original long-term contracts were expected to cost the State more than $40 billion over a 10-year timeframe [9]. The contracts were intended to cover about one-third of the IOUs' electricity demands. The average contract length of the DWR's original contracts is 10 years, and the average price has been estimated to be $70 per MWh. Nearly all of the contracts with terms shorter than 10 years are for energy provided by existing generating plants, as existing units do not require financing and therefore do not require the same contract duration as new plants. Over 60% of the electricity to be supplied over the 10-year period will come from newly constructed generators. The contracts include a mixture of baseload and peaking power, and dispatchable and non-dispatchable plants. Forty-one percent of the electricity is supplied in "tolling" agreements (i.e. where the Buyer pays for the right to use the Seller's power plant to convert natural gas to electricity), most of which give the DWR some flexibility to dispatch the facility. Fifty-nine percent of the electricity is supplied at fixed prices; these contracts are mostly non-dispatchable.

Detailed tables summarizing each of these contracts can be found in Bachrach et al. [4]. Tables 1 and 2 highlight some of the key elements of the long-term contracts. As shown, 87% of the electricity procured by the DWR under these long-term contracts is specifically designated to come from natural gas plants. Another

[8] The DWR used contract templates from the Edison Electric Institute and the Western Systems Power Pool.

Table 1
Comparison of key contract terms of the DWR long-term renewable and non-renewable contracts

| Contract terms | Renewable | Natural gas | Unspecified resources | Total contract sample |
|---|---|---|---|---|
| Number of contracts (% of total) | 7 (26%) | 17 (63%) | 3 (11%) | 27 (100%) |
| Weighted average[a] contract length (range of contract lengths) | 9.8 years (3–12) | 9.7 years (3–20) | 9.7 years (5–10) | 9.7 years (3–20) |
| Weighted average[a] contract price (dollars per MWh) | 66 | 70 | 62 | 69 |
| Fixed price contracts: | | 68 | | |
| Tolling contracts: | | 72 | | |
| Number of contracts with new units to be built | 6[b] | 13 | 0 | 19[b] |
| 10-year energy purchases[c] (% of total) | 8448 GW h (1.5%) | 506,885 GW h (86.7%) | 69,174 GW h (11.8%) | 584,506 GW h (100%) |
| 10-year power cost[c] (% of total) | $0.57 billion (1.4%) | $35.5 billion (88%) | $4.3 billion (10.6%) | $40.3 billion (100%) |

[a] The weighted averages are weighted by the amount of electricity to be provided by each contract through 2010.
[b] Includes two re-powered plants.
[c] Figures derived from spreadsheets provided by the State Auditor's office that were used in the State Auditor's report on the DWR contracts [9]. All dollars are in nominal dollars.

12% is to come from unspecified units, which are likely to be natural gas-fired power plants. Just 1.5% of the electricity is expected to come from renewable sources.[9]

The DWR's seven original renewable contracts total 247 MW of capacity, including 175 MW of wind, 44 MW of biomass, 25 MW of geothermal, and 3 MW of landfill gas. The biomass contracts have the shortest contract lengths (3–5 years) and the highest prices of the renewable contracts; the wind power contracts have the longest contract lengths (10–12 years) and the lowest prices of the renewable contracts. Furthermore, the wind power contracts, which dominate energy deliveries under the DWR's renewable purchases, are priced lower than all but three of the DWR's gas-fired electricity contracts.

## 4. Fuel price risk in electricity contracts

In this section, we examine how the long-term DWR contracts allocate and/or mitigate the risk that the price of fuel will exhibit variability. We begin by discussing fuel price risk fundamentals, and then turn to a detailed review of the DWR

[9] As will be discussed in more detail in a later section on environmental compliance risk, the DWR did not purchase the environmental attributes or renewable energy credits associated with the wind generation covered in this contract sample. Thus, the DWR did not, in fact, purchase "renewable energy" under these contracts, but rather acquired generic electricity from wind power plants.

Table 2
Comparison of key contract terms of the DWR long-term renewable electricity contracts

| Contract details | Wind | Biomass | Geothermal | Landfill gas | All renewables |
|---|---|---|---|---|---|
| Total capacity (MW) | 175 | 44 | 25 | 3 | 247 |
| Number of contracts | 2 | 3 | 1 | 1 | 7 |
| Weighted average[a] contract length (range of contract lengths) | 11.2 years (10–12) | 4.5 years (3–5) | 10 years | 5 years | 9.8 years (3–12) |
| Weighted average[a] contract price[b] (dollars per MWh) | 59 | 89 | 67 | 65 | 66 |
| 10-year energy purchases[b] (% of renewables total) | 5280 GW h (63%) | 1363 GW h (16%) | 1692 GW h (20%) | 112 GW h (1%) | 8448 GW h (100%) |

[a] The weighted averages are weighted the amount of electricity to be provided by each contract through 2010.

[b] Figures derived largely from spreadsheets provided by the State Auditor's office that were used in the State Auditor's report on the DWR contracts [9]. All dollars are in nominal dollars.

contracts. We find that renewable and gas-fired electricity contracts pose substantially different fuel price risks. The ability of renewable energy facilities to offer price stability is a frequently mentioned benefit of these energy sources [3,13–15]. It deserves note, however, that gas-fired generators can also offer fixed prices per MWh of electricity generated. As we will show, the DWR primarily protected itself from fuel price risk by contracting at fixed prices with natural gas-fired generators rather than opting for the (arguably) more complete physical hedge that renewable energy can provide.

### 4.1. Fuel price risk fundamentals

Fuel price risk is among the most significant risks in the electricity industry, and electricity contracts must therefore allocate the risk that the price of fuel will exhibit variability. A party's exposure to fuel price risk in an electricity contract depends on three factors: (1) the variability of the fuel's price, (2) the *allocation* of fuel price risk between the parties to the contract, and (3) the ability of a party to *mitigate* the risk to which it is exposed.

Among the fuels most commonly used to generate electricity, natural gas is the most volatile in price (see, e.g., Fig. 1). Long-term gas-fired electricity contracts generally allocate natural gas price risk through one of three pricing mechanisms: (1) fixed prices, (2) indexed prices, or (3) ''tolling'' agreements.

- *Fixed-price electricity contracts* establish a fixed and known price per MWh of delivered electricity. Such contracts clearly allocate fuel price risk to the generator (i.e. the ''Seller'') because the generator is responsible for selling electricity at fixed prices, while simultaneously dealing with an inherently variable fuel price stream. The Buyer may pay a premium for fixed-price contracts with natural gas generators because the Sellers have to manage the fuel price risk to which they are exposed, which may well increase their costs [13].

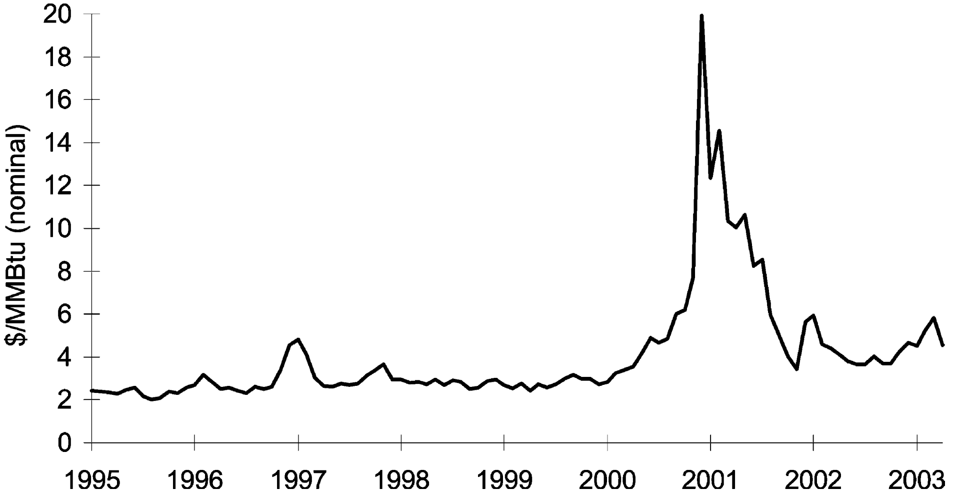


Fig. 1. Price of natural gas delivered to electric utility consumers in California.

- *Indexed-price contracts* generally index the price of electricity to either inflation or to the cost of another commodity, for example, the cost of the fuel used to generate the electricity [7]. When electricity contracts are indexed to the price of the natural gas used to generate the electricity, the fuel price risk is allocated to the Buyer because the Buyer receives a variable-priced product.
- *Tolling contracts* provide the Buyer a service: the right to use the Seller's power plant to convert natural gas to electricity. The Seller is paid not only for the use of its facility, but also for simply being available to generate. The Buyer pays for the natural gas used to generate the electricity. The risk of fuel price variability is therefore clearly allocated to the Buyer in tolling contracts. The Buyer can then choose to reduce its fuel price risk exposure through fixed-price physical gas supply contracts, gas storage, or financial hedging instruments.

In contrast to the volatility of natural gas prices, renewable resources in general have a less-variable and frequently free fuel cost stream,[10] typically resulting in less fuel price risk for either party to an electricity contract. Hence, it is more common to have fixed-price contracts for renewable electricity than for natural gas-fired electricity [13].

Since the use of renewable resources decreases fuel price risk for both parties to a contract, all else equal, a fixed-price renewable electricity contract is arguably a more complete hedge against fuel price risk for the Buyer than is a fixed-price contract for natural gas generation. This is because the Buyer of a fixed-price gas-

[10] Wind, sunlight, water, geothermal heat, and landfill gas are all renewable resources that provide "free" fuel to generate electricity (fuel collection/conversion, of course, is costly in all cases). Biomass is a renewable fuel that can either be free or have a variable cost.

fired electricity contract still bears some residual fuel price risk in the event that the Seller defaults on the contract because of a natural gas price increase, therefore exposing the Buyer to the short-term market for electricity purchases. Experience shows that the risk of contract default or renegotiation in such cases can be significant for gas-fired generation [16], though the absolute magnitude of this risk deserves additional analysis. More generally, if an increase in renewable electricity generation reduces natural gas consumption on a regional or national basis, then it will put downward pressure on natural gas prices overall, resulting in an economic benefit to consumers [17]. On the other hand, the intermittent nature of some renewable fuels may require short-term purchases of un-hedged fossil generation, thereby reducing the hedge benefits that renewable energy otherwise provides.

### 4.2. Fuel price risk in the DWR contract sample

The majority of the electricity DWR has under contract for the next decade will come from power plants fueled by natural gas—a fuel whose price has exhibited substantial volatility. In fact, natural gas price increases in California contributed to the extremely high wholesale electricity prices that caused California's electricity crisis.

Against this backdrop, the DWR hedged its fuel price risk exposure primarily through the use of fixed-price non-renewable (primarily natural gas) electricity contracts. These contracts provide 57% of the total electricity the DWR has under contract through 2010, and demonstrate that fuel price risk can be hedged to some degree through fixed-price contracts with gas-fired generators.

Another 41% of the DWR's electricity supply will come through tolling contracts, in which the DWR directly bears fuel price risk.[11] (The DWR did not use index-based electricity contracts.) Tolling agreements do, however, allow the Buyer to choose the level of natural gas price risk exposure it desires. The DWR, for example, can manage its fuel price risk by signing a long-term fixed-price contract for natural gas supply, by agreeing with the Seller on a fuel supply plan that meets the DWR's risk exposure needs, or else by purchasing natural gas on the spot market and using financial instruments to hedge the price volatility.

Almost all of the tolling contracts in the DWR sample allow the DWR to dispatch the power plant. In effect, under a tolling agreement with a dispatchable plant, the DWR accepts fuel price risk in exchange for a reduction in its exposure to demand risk (discussed in Section 6). The link between tolling and dispatchability is consistent with the desire of a Seller to avoid excessive fuel price risk—it would be risky for a Seller to agree to provide fixed-price energy and to let the DWR dispatch the facility, because the uncertain amounts of fuel required to generate power would make it difficult for the Seller to mitigate its fuel price risk exposure.

[11] Note that here and elsewhere we use percentage figures that are provided by the California State Auditor, and which assume that the DWR purchases the maximum amount of energy available under each contract, including the dispatchable contracts. As a practical matter, the DWR is unlikely to purchase this maximum quantity.

The elasticity of the total cost of the DWR contracts through 2010 to natural gas prices is only about 0.2. That is, a 10% increase in natural gas prices over a 10 year period will lead to a 2% increase in the DWR's power costs over that same time period. While this demonstrates that the DWR has protected itself reasonably well against movements in natural gas prices, the sheer size of the DWR's contracting efforts means that its exposure to natural gas price increases could be significant in absolute figures. For example, the DWR's total cost over 10 years could vary on the order of $2 billion based on reasonable scenarios of future natural gas prices [4].

More generally, the DWR contracts provide for the construction of a significant number of new natural gas power plants, which will increase California's reliance on natural gas and may have important implications for the vulnerability of the State's economy to natural gas price volatility. The DWR's recently renegotiated contracts convert some of the fixed-price natural gas contracts to tolling agreements, potentially further increasing the DWR's fuel price risk exposure.

Renewable electricity only provides 1.5% of the DWR's total 10-year electricity purchases. The DWR's renewable energy contracts are all at fixed prices, illustrating the ability of renewable generators to offer a hedge against fuel price movements. These contracts, especially those with wind, geothermal, and landfill gas generators, provide the greatest possible mitigation of fuel price risk for both the DWR and the Sellers.[12] For the DWR, the mitigation of fuel price risk provided by these renewable energy contracts is arguably greater than that provided by fixed-price natural gas contracts or hedged tolling agreements, because of the default risks described earlier.

In sum, these renewable electricity contracts *reduce* fuel price risk for both parties, whereas hedged natural gas contracts simply *shift* fuel price risk to other parties. Nonetheless, with such a small amount of renewable energy under contract, the DWR clearly did not use renewables as a significant hedge against fuel price risk, despite the fact that renewable energy offers a more complete hedge than fixed-price gas-fired electricity contracts.

## 5. Fuel supply risk in electricity contracts

This section addresses fuel supply risk: the risk that the fuel supply to a power plant will be unreliable, resulting in the inability to generate electricity in a predict-

[12] Since the DWR's biomass contracts are fixed-price, the Sellers bear the biomass price risk. Similar to the fixed-price natural gas contracts, the DWR still bears some residual fuel price risk (i.e. contract default risks) in the biomass contracts. Biomass contracts have at least one advantage and one disadvantage compared to natural gas contracts. Since fuel supply for biomass power plants is local by nature, the volatility of biomass prices is less systematic than natural gas prices—that is, a spike in biomass prices at one plant will not necessarily affect the price of fuel for all biomass generators in the State simultaneously. On the other hand, there is no index price for biomass, which makes it difficult to hedge biomass price risk with financial instruments; the Seller's only option is to contract for fixed-price physical supply to mitigate its fuel price risk exposure.

able and dependable manner. We find that renewable electricity contracts and natural gas-fired electricity contracts face different challenges with regards to fuel supply risk. Natural gas-fired power plants are more vulnerable to systematic and catastrophic interruptions in fuel supply (affecting many plants simultaneously), while renewable generation is sometimes far more vulnerable to "normal" day-to-day variability in fuel supply. These differences are reflected in the DWR contract sample.

### 5.1. Fuel supply risk fundamentals

The ability of a power plant to reliably generate electricity depends, in part, on the dependability of its supply of fuel. Non-renewable and renewable power plants face different challenges in obtaining reliable supplies of fuel.

The reliability of the supply of natural gas to a power plant depends on both the reliability of the supply of the gas itself, and the reliability of the transportation of the gas to the plant. The supply of natural gas to a power plant can be interrupted due to "normal" supply and transportation constraints (e.g., pipeline constraints), or due to catastrophes. The parties to an electricity contract can usually manage the risk of a "normal" natural gas supply or transportation constraint by requiring firm (as opposed to interruptible) fuel and transportation contracts. Such contracts ensure the Buyer that they have a financial and contractual right to natural gas supply and transport in the case of supply and/or transportation constraints, whereas interruptible contracts have less surety of delivery in these instances. On the other hand, the risk of a catastrophic interruption of natural gas supply (e.g., an attack on the pipelines that bring gas into California) cannot be readily reduced through the terms of an individual contract (i.e. not even a firm contract can result in the delivery of gas in the midst of catastrophic events). Consequently, contracts for electricity mostly *allocate* the remaining risk of a fuel supply interruption rather than further *reducing* the risk. From the perspective of maintaining a reliable supply of electricity, the risk of a catastrophe is much more serious than a "normal" gas supply or transportation constraint, because it is unpredictable and systematic—it affects numerous power plants simultaneously—potentially causing widespread disruptions to the electricity grid. This risk can only be reasonably managed through resource diversification.

The supplies of many renewable fuels used to generate electricity are often less predictable on an hour-to-hour and day-to-day basis than the supply of natural gas. Solar and wind resources have a significant amount of hourly, daily, and seasonal variation that is difficult to predict with precision in advance, although improvements in prediction methodologies are reducing the associated uncertainties. Landfill gas and geothermal resources have much less day-to-day variation, but their supply can be unpredictable over longer time scales. Biomass facilities have to acquire and transport fuel to the plant; accordingly, biomass electricity contracts can manage fuel supply risk in a similar manner to natural gas contracts, by requiring firm fuel and transportation contracts from biomass suppliers.

In some cases, renewable fuel supply variability is systematic, for example, cloudy weather can reduce solar energy production on a statewide basis. In contrast to natural gas fuel supply risk, however, uncertainty in renewable fuel supply is frequently unsystematic, affecting individual renewable plants or resource areas, but not affecting all plants simultaneously. For example, studies have shown that geographic dispersion of wind facilities can significantly "smooth out" the overall production pattern of the wind plants in aggregate [18].

### 5.2. Fuel supply risk in the DWR contract sample

The DWR bears some fuel supply risk in all of its contracts, whether renewable-based or natural gas fueled.

Since fuel supply interruptions are often likely to be out of the Seller's control, the DWR's natural gas contracts generally excuse the Seller from delivering power in the event of a fuel supply interruption if the Seller has firm fuel supply and transportation arrangements. In the DWR's fixed-price non-renewable contracts, for example, the Seller is responsible for procuring the fuel supply and fuel transportation necessary to generate the electricity to be provided under the contract. Although almost none of these contracts *explicitly* allocate the risk of a fuel supply or transportation interruption, these contracts *implicitly* excuse the Seller from providing power—through force majeure clauses—if a fuel interruption is out of the Seller's control, and not due to negligence (e.g., not having arranged for firm fuel supply). If the Seller has an interruptible fuel supply or transportation contract that is interrupted, however, the outage would presumably *not* be excused, and the Seller would have to pay DWR's cost of replacement power ("cover damages") and/or would be penalized according to the contract's availability provisions (see Section 7).

Similar to the fixed-price non-renewable contracts, the DWR's natural gas tolling contracts allocate much of the fuel supply risk to the DWR. Nine of the DWR's 11 natural gas tolling contracts explicitly excuse the Seller from delivering power if the fuel supply or fuel transportation to the plant is interrupted. If a contract does not explicitly address the risk of a fuel supply or fuel transportation interruption, then the allocation of the risk is determined by the contract's force majeure clause. Unlike the fixed-price non-renewable contracts, however, only three of the tolling contracts require the Seller to pay the DWR cover damages if the Seller has an unexcused outage due to a fuel interruption. That said, most of the tolling agreements penalize the Seller for not meeting availability requirements; for the most part, the contracts require availabilities of over 95% during the summer and over 90% during the rest of the year.[13]

[13] The general definition of availability in dispatchable contracts is the number of hours that the generation unit was *available* to generate power during a period, divided by the total possible number of hours the unit could have been dispatched during the period as specified in the contract (adjusted for force majeure events and scheduled outages).

The DWR therefore bears the risk of a catastrophic natural gas supply interruption in all of its non-renewable contracts. The DWR also bears the risk of other, less dramatic fuel supply or fuel transportation interruptions in most of the gas-fired electricity contracts, though requirements for firm gas supply and transportation delivery in some of the contracts mitigate this risk. Moreover, since the DWR contracts increase California's overall reliance on natural gas, the contracts may make the State's electrical grid more vulnerable to natural gas supply interruptions.

The DWR contracted for electricity from four different renewable resources: wind, geothermal, landfill gas, and biomass. Renewable energy contracts may help diversify the DWR's fuel supply portfolio and thereby decrease the risk that a systematic natural gas supply interruption will disrupt California's electrical grid.[14] That said, each renewable resource faces different challenges with regards to fuel supply risk, and in all but one of the DWR's renewable contracts, the DWR bears some fuel supply risk.

In aggregate, "normal" hourly, daily, seasonal, and yearly variations in fuel supply are a larger concern in the DWR's renewable energy contracts than they are in the natural gas contracts. The DWR's wind power contracts, for example, offer as-available[15] supply and therefore the Buyer must manage considerable hourly, daily, and seasonal supply variations.

The DWR's other renewable energy contracts do not have as variable a fuel supply and can therefore provide a firmer supply of electricity, but even these contracts expose the DWR to a greater degree of "normal" variability in supply than do the DWR's natural gas contracts. For example, in the geothermal contract, the Seller is excused from performance due to problems with the geothermal steamfield. The landfill gas contract, meanwhile, is a unit-contingent contract, and therefore excuses the Seller from delivering power whenever the plant is unavailable due to an outage. The Seller is required, however, to generate power at the plant's "maximum capability" in every hour, to operate the plant such that the monthly actual generation is within $\pm 10\%$ of the monthly scheduled generation, and to meet minimum availability thresholds. Two of the three biomass contracts are structured similarly, while a final biomass contract provides a greater assurance of fuel supply availability.

## 6. Demand risk in electricity contracts

As illustrated in this section on demand risk, the DWR primarily managed its need to instantaneously meet electricity demands by purchasing about one-quarter of its total electricity through dispatchable natural-gas contracts. None of the

[14] A systematic fuel supply interruption would have large economic repercussions, so although the probability of a systematic interruption may be small, there may be considerable value in reducing the risk.

[15] As-available contracts allow the power plant to sell electricity whenever it is able to generate it.

DWR's renewable contracts are dispatchable, and most of the renewable contracts do less to mitigate the DWR's demand risk than even the non-dispatchable natural-gas contracts. In particular, with one exception, the renewable contracts do not offer fixed energy delivery schedules.

### 6.1. Demand risk fundamentals

Electricity is a unique commodity because it must be simultaneously produced by the supplier and utilized by the customer in real time. The owner of a portfolio of electricity supplies may therefore be required to design and operate the portfolio to be able to supply electricity to follow its customers' load. Since electricity demand is variable and uncertain, the parties to electricity contracts face "demand risk": uncertainty over whether the electricity that has been contracted for will be sufficient (but not overly sufficient) to meet load.

Dispatchable power plants are better able to respond to changes in electricity demand, thus mitigating demand risk. A dispatchable contract allows the Buyer to tell the Seller how much electricity to generate and when to do so, within specified constraints. Utilities or other load-serving entities, however, only need enough dispatchable power to "top-off" the electricity provided by non-dispatchable plants. A least-cost electricity supply portfolio will therefore typically contain a substantial amount of non-dispatchable electricity generation, and even energy efficiency resources. Non-dispatchable contracts generally deliver "blocks" of power (fixed amounts of electricity) during hours that are set in the contract. Non-dispatchable power is more valuable if it is delivered during peak periods and if it is for firm delivery.

Renewable generation technologies are typically more difficult to dispatch than natural gas-fired generation technologies. Some forms of renewable electricity may also deliver more power during off-peak periods than conventional energy sources, and may not be willing or able to offer fixed blocks of delivered electricity, preferring, instead, as-available delivery.[16] As a result, intermittent energy sources are noted to require certain "integration" costs, typically calculated to be under 0.5 cents/kWh, and renewable generators may not have as much "capacity value" as conventional generation sources [19,20].

### 6.2. Demand risk in the DWR contract sample

The DWR reduced its exposure to demand risk primarily by purchasing about one-quarter of its total electricity through dispatchable natural-gas contracts. These contracts allow the DWR to dispatch the specified power plants either the day before the electricity is needed, on a real-time basis, or both. The contracts contain numerous constraints on how the DWR is allowed to dispatch the power plants, however, in large part to ensure that the power plants are run within their

[16] On the other hand, renewable generation facilities may be able to reduce demand risk by providing increased flexibility due to short construction lead-times and the modular nature of certain technologies [2]; certain natural gas-fired generation facilities (e.g., peakers) also have these characteristics.

technical operating limits and are not unduly stressed (for details, see Bachrach et al. [4]). The DWR further reduced its demand risk by (1) tailoring, to some degree, the delivery pattern of its non-dispatchable natural-gas contracts to the utilities' expected load requirements,[17] and (2) imposing restrictions on the timing of routine power plant maintenance.[18]

While the dispatchable contracts reduce the DWR's demand risk, they also increase the DWR's exposure to fuel price risk because almost all of the dispatchable contracts are natural gas tolling agreements. This highlights a fundamental tradeoff between demand and fuel price risks.

Moreover, despite the provisions discussed above, since almost three-quarters of the DWR's energy is non-dispatchable, the DWR contracts arguably did not do enough to combat demand risk. In particular, the California State Auditor's analysis of the DWR contracts found that the DWR's overall portfolio of electricity contracts includes excess deliveries of baseload energy and insufficient deliveries of (or insufficient dispatchable deliveries of) peak electricity [9]. This has, in fact, required the DWR to sell some of its excess power at a loss.

The renewable energy contracts signed by the DWR are all non-dispatchable, representing a lower value product than a dispatchable source (all else being equal). With one exception, the renewable contracts do not offer fixed energy delivery schedules that are established well in advance of delivery, and therefore provide more variable and uncertain output profiles than the non-dispatchable contracts for conventional energy supplies. In particular, one of the biomass contracts is similar to many of the non-dispatchable natural-gas contracts: electricity is to be supplied according to a schedule fixed in the contract. The DWR has slightly less certainty in energy deliveries in the landfill gas, geothermal, and the other biomass contracts, however, because all of these contracts simply require the Seller to supply electricity at the power plants' "maximum capability" (with some restrictions).[19] The DWR's two wind power contracts provide the least certainty to the DWR because they supply electricity on an as-available basis, and because the electricity deliveries are neither dispatchable nor predictable significantly in advance of delivery.

In sum, the renewable contracts do less to mitigate DWR's demand risk than even the non-dispatchable natural gas contracts. The renewable contracts,

[17] All but two of DWR's original non-dispatchable, non-renewable contracts specify how much electricity the Seller will deliver and when (the delivery schedule). Since the DWR cannot choose when to have electricity delivered in these contracts (after a contract is finalized), these contracts do not directly and completely mitigate DWR's demand risk. Because some of the contracts require delivery during peak periods, however, they do mitigate DWR's demand risk somewhat.

[18] In general, many of the contracts require the Seller to avoid performing maintenance during the summer months and during peak hours, when it may be the most difficult for the DWR to procure replacement energy.

[19] Many of these contracts require the Sellers to deliver within $\pm 10\%$ of the monthly schedules that they submit to the DWR. In addition, if the Seller makes a same-day change in its schedule that results in an increase to its output, the DWR has the right, but not the obligation, to purchase the increase at the contract price.

however, represent a small fraction (less than 2%) of the non-dispatchable energy under contract. Moreover, demand risk can readily be managed through dispatchable natural gas contracts and non-dispatchable contracts with tailored delivery patterns. Accordingly, a certain amount of renewable energy can be integrated into electricity systems with effectively no or limited incremental cost [19]. Therefore, despite the fact that some of the DWR's renewable contracts do less to reduce demand risk than the DWR's natural gas contracts, the DWR's renewable contracts in aggregate impose little risk on the State.

## 7. Performance risk in electricity contracts

This section turns to the issue of performance risk. As shown below, the DWR's contracts provide a number of incentives and penalties to the Sellers to mitigate performance risks. Major differences in how performance risk is handled exist between the DWR's dispatchable and non-dispatchable contracts. We find that the treatment of performance risk in the renewable contracts is largely similar to, though a bit more lenient than, the treatment of those same risks in the non-dispatchable, non-renewable contracts.

### 7.1. Performance risk fundamentals

Performance risk is defined here as the risk that the Seller may not be willing or able to deliver electricity according to the contractually prescribed requirements in terms of time and quantity. Performance risk is subject to better control and management (as opposed to just allocation) than any other risk discussed in this paper; because, for example, the Seller is frequently able to control the performance of its power plant(s) to a very high degree. Contracts therefore allocate a substantial amount of performance risk to the Sellers, and provide penalties and incentives to ensure that the Sellers perform adequately [7].

To the extent that renewable generation is based on a variable underlying fuel stream (e.g., wind), some renewable contracts clearly cannot have the same requirements for energy delivery as can a contract for natural gas-fired generation. These issues of dispatchability, controllability, and predictability are covered in the previous "demand risk" section of this article (Section 6). In the present section, we define performance risk more narrowly, and examine the more limited and mundane clauses that penalize or encourage parties to a contract to meet their contractually determined delivery requirements, whatever those might be.

Our analysis of performance risk is divided into two periods: (1) during the construction of a power plant, and (2) during the operation of a power plant. The major sources of uncertainty during the construction of a power plant are whether the plant will be built on time, and whether the plant will be built within budget. The major sources of uncertainty during the delivery period of an electricity contract are how efficiently the power plant will be operated, and how reliably the Seller will supply the amount of energy or capacity that was contracted for.

The allocation of performance risk during the delivery period of a contract is managed in part by the firmness of the contract, which determines under what cir-

cumstances the Seller is excused from delivering electricity. Most contracts are for either "unit-contingent" or "firm" electricity products (some of the renewable contracts are "as-available", which can be viewed as a particularly lenient unit-contingent contract). A unit-contingent contract excuses the Seller from delivering power when the Seller's specified generating facilities are unavailable either due to a forced outage (e.g., a maintenance outage), or to an event of force majeure. Firm contracts only excuse the Seller's performance during an event of force majeure; an event of force majeure is typically defined as a circumstance that prevents a party from performing its obligations, that is not within the reasonable control of (or the result of negligence of) the party, and which the party cannot overcome by the exercise of due diligence. The definition and interpretation of force majeure clauses can strongly influence the amount of performance risk that each party to a contract bears.

### *7.2. Performance risk in the DWR contract sample*

Overall, we find that the DWR's long-term electricity contracts provide for the construction of a significant amount of new generation capacity in California, while exposing the DWR to only a minimal amount of the risk of construction cost over-runs. Not surprisingly, all but one of the DWR contracts that require new plant construction (whether renewable or natural gas) allocate the risk of construction cost over-runs to the Seller. In most of the contracts, the parties share the risk that the power plant will not be built according to schedule; most contracts allow the DWR to terminate the contract if a unit does not reach operation by a specified deadline, however, and in some contracts the Seller must also pay a financial penalty.

During the delivery phase of the contracts, there are considerable differences in the treatment of performance risk between the DWR's dispatchable and non-dispatchable contracts, regardless of fuel source.[20]

- The DWR's *dispatchable* gas-fired contracts are expected to deliver over 25% of the DWR's energy over the next decade, and are commonly tolling agreements. In all of these contracts, the DWR pays the Seller both a "capacity charge" for making the power plant available to the DWR (regardless of whether or not the DWR requests that the plant generate power), and an energy charge for the electricity that is actually delivered. In addition, under the tolling contracts, the DWR must pay for the fuel used to generate electricity. These dispatchable contracts contain four key methods to control performance risk. First, many of these contracts require annual testing of the capacity of the power plant to determine the capacity charge. Second, many of the contracts require periodic testing or calculation of the plant's heat rate to protect against degradation in the

[20] It deserves note that the California State Auditor [9] expressed concern that many of the contracts contain performance risk terms that are excessively lenient for the Sellers; many of the renegotiated contracts strengthen the performance risk terms.

efficiency of the plant, because the DWR's fuel costs under the tolling contracts depend on this efficiency. Third, most of the contracts have availability requirements to ensure that the power plant is available to generate power when needed, and the contracts financially penalize the Seller if the availability requirement is not met; most of these contracts guarantee availabilities of over 95% during the summer and over 90% during the rest of the year. Finally, some of the dispatchable contracts require the Seller to pay "cover damages" for unexcused failures to deliver scheduled power; which outages qualify as excused outages is determined by the "firmness" of the contract (unit-contingent contracts excuse the Seller from delivering power during generator outages and events of force majeure, while firm contracts only excuse the Seller during events of force majeure).
- The DWR's original *non-dispatchable* non-renewable contracts, which were expected to provide 70% of the DWR's energy over the next decade, have fewer performance concerns to manage than the dispatchable contracts. Because the Seller is only paid when electricity is delivered (unlike the dispatchable contracts, which also contain capacity payments), the non-dispatchable contracts provide the Seller a built-in incentive to perform. Partly as a result, these non-dispatchable and predominantly natural gas-fired contracts have fewer clauses designed to manage performance risk than do the dispatchable natural-gas contracts. Nonetheless, all of the DWR's non-renewable, non-dispatchable contracts require the Seller to pay cover damages for unexcused failures to deliver power. Whether a failure to deliver is excused or not is dependent, in part, on whether the contract is for unit-contingent or firm delivery. The only other performance penalty contained in the DWR's non-dispatchable, non-renewable contracts is an availability guarantee, contained in only two contracts.

The DWR's renewable energy contracts are all non-dispatchable, and are therefore best compared to the DWR's other non-dispatchable contracts. To the extent that renewable generation is based on a variable underlying fuel stream, some renewable contracts clearly cannot have the same requirements for energy delivery as can a contract for natural gas generation. While some sources of renewable energy are therefore held to lower energy delivery standards than are natural gas plants (see the previous section on demand risk), we find that the treatment of performance risk in the renewable contracts is largely similar to, though a bit more lenient than, the treatment of those same risks in the DWR's non-dispatchable contracts for conventional energy discussed above.

Although it is not clear how such differences relate to the underlying characteristics of the technologies themselves, one of the differences between the performance risk clauses in the renewable and natural gas-fired contracts is that the renewable contracts do not financially penalize the Seller if a power plant is delayed in reaching commercial operation (other than allowing the DWR to terminate the contract), whereas several of the natural gas contracts contain penalties in addition to the DWR's termination rights. The DWR also assumed additional performance risk in the two wind contracts by agreeing to bear any "imbalance

charges" imposed by the California Independent System Operator (ISO) that might arise due to imprecise wind output scheduling, which is an aspect of performance risk that is not a significant concern in the other DWR contracts.[21] The use of cover damages and availability guarantees also differ somewhat between the DWR's renewable and non-renewable contracts (see Bachrach et al. [4]).

## 8. Environmental compliance risk in electricity contracts

This section addresses environmental compliance risk. As shown, if new environmental regulations are enacted, parties to fossil fuel-based contracts will likely bear additional costs not imposed on parties to renewable contracts. Surprisingly, a number of the DWR's gas-fired contracts do not allocate the risk of future environmental regulations in a comprehensive manner; those that do, allocate much of the risk to the DWR and therefore ratepayers. The DWR's renewable energy contracts will reduce aggregate exposure to environmental compliance risk, but the DWR may not fully capture these benefits because some of the contracts allow the Seller to retain the rights to the renewable energy attributes.

### *8.1. Environmental compliance risk fundamentals*

The laws and regulations governing the environmental impacts of electricity generation, along with the cost of compliance with existing environmental regulations, are likely to change within the term of many of the DWR's contracts and long-term electricity supply contracts more generally. These environmental compliance risks can impose potentially large costs on the parties to an electricity contract (see, e.g., [21,22]). Some possible future environmental regulations include a carbon tax (or other form of carbon regulation), a renewables portfolio standard, and further regulation of sulfur dioxide, nitrogen oxides, fine particulates, and mercury emissions [23].

Electricity contracts must therefore manage environmental compliance risk: the risk related to compliance with existing environmental requirements, and the risk that future environmental regulations will affect the cost of generating electricity. When deciding what electricity contracts to sign, an electricity purchaser should therefore account for the possible future costs of environmental compliance to which the purchaser would be exposed. Likewise, when Sellers of electricity are exposed to environmental compliance risks, they will presumably increase the contract price to account for the cost of bearing the risks.

Environmental compliance risks are heavily dependent on the fuel source and technologies used to generate electricity. Fossil generation technologies are generally believed to cause more environmental damage than renewable generation technologies, and renewable electricity contracts can therefore mitigate environmental compliance risks. If new environmental regulations are enacted, parties to gas-fired

[21] The ISO subsequently revised its rules to facilitate the use of intermittent energy sources, which will effectively eliminate the DWR's potential cost exposure.

electricity contracts will most likely have to bear additional costs not imposed on parties to renewable contracts, who may even realize financial benefits stemming from a new regulation.

Though aggregate environmental compliance risk exposure is determined in part by the type of power plants used to generate electricity, the incidence of those risks on the Buyer or the Seller depends on their specific allocation in electricity contracts. Electricity contracts can allocate the cost of future environmental compliance to either the Buyer or the Seller, or the contract can split the risk between the parties. Since there are numerous sources of environmental risk, it is very unlikely that a contract could allocate *all* environmental risk to one party or the other; rather, the allocation of environmental risk is typically multi-dimensional, with different environmental risks allocated between the parties in different ways.

Finally, when the environmental compliance risk is due to a possible future regulation, the amount of risk to which a party is exposed is also determined by the details of how the new regulation is implemented. For example, if a future carbon tax were levied on the use of natural gas, by default the Seller would bear the cost of the carbon tax in most contracts (with the possible exception of tolling agreements). If the carbon tax were instead levied on the use of electricity, however, the Buyer could bear the cost. Of course, new environmental regulations might also "grandfather" existing power plants and excuse them from being subject to the new regulation altogether.

### *8.2. Environmental compliance risk in the DWR contract sample*

#### *8.2.1. Compliance with current environmental regulations*

Once a power plant has been built, the plant must remain in compliance with existing environmental regulations and, sometimes, acquire air pollution allowances on an ongoing basis in order to operate. The DWR contracts mostly allocate the risk of compliance with *current environmental regulations* to the Seller; approximately half of the contracts assign the cost of complying with existing regulations to the Seller explicitly, while the other half do so by default. If the cost of meeting these existing regulations increases, it is the Seller that bears most of the cost.

There are some notable exceptions, however, and three contracts with conventional power plants allocate the cost of acquiring pollution permits to the DWR. The California State Auditor [9] presents an analysis of these unusual contract clauses, and estimates that one of the contracts alone could expose the DWR to between $400 million and $688 million in additional costs over the lifetime of the contract, or between 0.7 and 1.2 cents per kWh. Similarly, the two additional contracts could expose the DWR to costs on the order of $300 million.

None of the renewable energy contracts allocate responsibility for acquiring environmental permits to the DWR.

#### *8.2.2. Compliance with new environmental regulations*

Given the potential financial impact of *new environmental regulations*, it is perhaps surprising that only 35% of the DWR's original non-renewable contracts (representing 45% of the DWR's contracted energy) explicitly allocate the risk of

future environmental regulations in a comprehensive manner.[22] Of those contracts that do comprehensively and explicitly allocate environmental compliance risks, most allocate a sizable portion of those risks to the DWR and therefore the State's electricity ratepayers (a number of the contracts require the Seller to cover the costs up to a ceiling, with the DWR bearing the remaining environmental compliance costs). The fact that many of the contracts fail to allocate this risk explicitly and comprehensively may be attributed to either a lack of concern about the cost of future environmental regulations or a lack of awareness of their potential cost.

Despite the ambiguity in many of the contracts, 17 of the DWR's original 20 long-term non-renewable contracts appear to allocate at least some of the risk of future changes in environmental regulations to the DWR. There are numerous differences in the ways the contracts allocate this risk, however, and there does not appear to be an "industry standard" approach to the treatment and allocation of future environmental compliance risk. The non-renewable contracts can be divided into two broad categories: (1) contracts that only allocate the risk of a future change in regulation that is targeted at energy services, and (2) contracts that allocate the risk of a future change in regulation more generally.

Seven of these 17 contracts (representing 27% of the non-renewable energy under contract) fall within the first category, and only address the risk of a future change in regulation in a limited way. In these cases, the allocation only applies to regulatory changes that are targeted at energy services, and most of the clauses only apply to changes implemented by the State of California.[23] While it is unclear whether such limited contract clauses would apply to new environmental regulations, it is clear that these contracts do not comprehensively allocate environmental compliance risks.

The other 10 non-renewable contracts (representing 63% of the non-renewable energy under contract) fall within the second category. These contracts allocate the risk of a *general* change in regulations, rather than only the risk of regulatory changes that are targeted at energy services. These contracts can be further grouped into two broad categories: (1) contracts that allocate the cost (sometimes above a threshold) of a new regulation to the DWR (eight of 10 contracts fall in this category), and (2) contracts that require the parties to the contract to negotiate how to share the costs (sometimes above a threshold) of a new regulation (two of 10 contracts fall in this category). Some of the contracts also restrict the applica-

[22] All other contracts only allocate the risk of regulations passed by either the federal or state government, or only regulations that are targeted at "energy services".

[23] For example, one particular contract contains the clause "[Seller] shall be entitled to pass through [to the DWR] any liability, loss, cost, damage and expense, including gross-up, arising out of a tax or other imposition enacted by the California state legislature after the date of this Agreement that is not of general applicability and is instead directed at the generation, sale, purchase, ownership and/or transmission of electric power, natural gas and/or other utility or energy goods and services. [DWR] shall be entitled to the benefit or reduction of or credit with respect to any such tax or other imposition enacted by the California state legislature after the date of this Agreement".

bility of an environmental compliance risk clause based on the governmental authority that implements the new regulation (e.g., a federal authority vs. a state authority).

By way of example, four of the original contracts pass on to the DWR any cost increase (above thresholds of either $0.50 or $5.00 per MWh) due to actions by any governmental entity. Another contract only passes on to the DWR an increase or decrease in costs due to actions of a *state* governmental authority, while another contract simply states: "[the Seller] shall not suffer the effects of any costs or restrictions imposed by environmental agencies whenever incurred that are associated with providing energy under the contracts". Two additional contracts provide that the parties to the contract will negotiate how to share the costs of a new regulation rather than specifically defining how the costs will be shared in advance. Additional details of these contract clauses can be found in Bachrach et al. [4].

For those contracts that do not explicitly allocate the risk of a general change in regulations, those risks are implicitly allocated based on the point of power delivery (i.e. the transmission system in the relevant ISO congestion zone). All costs up to the delivery point are born by the Seller, while all costs after the delivery point are born by the DWR. Thus, as discussed above, the implementation details of a new regulation could have a large effect on which party bears the cost. Of course, if a contract does not explicitly allocate the risk of a new regulation, and one is enacted, it is likely that the parties will litigate the matter.

Based on the preceding discussion, it is apparent that the DWR and the State's electricity customers may be exposed to significant financial costs if new environmental regulations are implemented; this may be especially true for carbon regulation because the DWR's contracts are predominantly for relatively clean-burning (in terms of criteria pollutants such as $NO_x$, $SO_2$, particulates, and mercury) natural gas plants. In the extreme, assume that the DWR bears the cost of carbon regulation for *all* of its non-renewable contracts. If the carbon regulation led to a carbon allowance price of $10 per metric ton, DWR's cumulative additional costs over the 2003–2010 timeframe would range from $855 million (0.15 cents per kWh) if the tax were implemented in 2003 to $108 million (0.02 cents per kWh) if the tax were implemented in 2010.[24] Similarly, with a carbon allowance price of $100 per metric ton, the DWR's cumulative exposure from 2003–2019 could range from $8.5 billion (1.5 cents per kWh) if the tax were implemented in 2003 to $1 billion (0.2 cents per kWh) if the tax were implemented in 2010.

The DWR's renewable energy contracts generally reduce aggregate exposure to environmental compliance risk because many renewable electricity sources are unlikely to be subject to future environmental regulations that greatly impact the operating costs of existing plants. Perhaps because of this, environmental com-

[24] Carbon emissions are calculated for all of the non-renewable contracts assuming an average emission rate for natural gas generation of 160.79 metric tons of carbon per GW h [24]. For various estimates of carbon allowance prices, see [24–26].

pliance risk is only explicitly allocated in one of the seven original renewable energy contracts.

If new environmental or renewable energy regulations are enacted, however, the question of which party to a renewables contract receives the benefits of the renewable plant's environmental performance may arise. At the time of contract execution, the possibility of a state renewables portfolio standard (RPS) should have been of particular concern. An RPS requires providers of electricity to purchase a minimum quantity of renewable energy. An RPS was in fact adopted in California subsequent to the DWR's execution of its long-term contracts.

An important question under California's RPS is which party in the DWR's contracts receives credit for the renewable attributes of the underlying electricity? Under these contracts, it turns out that DWR will not fully benefit from the benefits renewable energy can provide, because some of those benefits were not allocated to the DWR. For example, both of the wind power contracts allow the Seller to retain the rights to the renewable attributes of the electricity, i.e. the renewable energy credits (RECs). Consequently, although the DWR is nominally purchasing 1.5% of its electricity from renewable sources under long-term contracts, only about 0.5% of the DWR's electricity comes with the RECs attached. Now that an RPS has been passed into law in the State, it can be shown that the DWR's decision to forfeit the rights to the RECs may expose the State to as much as $40–80 million in additional costs [4].

## 9. Regulatory risk in electricity contracts

This section addresses regulatory risk more broadly than in the previous section, which addressed only environmental regulatory risk. As shown here, both renewable and non-renewable contracts face similar regulatory uncertainties. Despite this, the DWR's gas-fired electricity contracts contain clauses designed to both prevent regulatory action, and to mitigate and allocate the consequences of new regulatory requirements. In contrast, none of the renewable contracts attempt to prevent regulatory review of the contracts, and only two of the seven contracts designate a course of action that will be taken if a regulatory agency orders a change in the contract.

### 9.1. Regulatory risk fundamentals

The electricity industry in the US is regulated by agencies at both the state and federal levels, and over the past decade the country's electricity industry has been subject to a great deal of regulatory uncertainty. We define regulatory risk as the possibility that future laws and regulations will alter the benefits or burdens of an electricity contract.

Regulatory risk can be divided into two broad categories: (1) the possibility of changes in general regulations or laws that would affect all or most electricity contracts, for example, a nationwide carbon tax, and (2) regulatory requirements targeted at a specific contract, for example, a ruling to modify a contract's price. The

first category of regulatory risk was covered, in part, by our discussion of environmental compliance risk. In this section, we discuss only the second category of regulatory risk: regulatory requirements targeted at specific contracts.

Parties to an electricity contract can take two approaches in managing regulatory risk. First, contracts can try to prevent regulatory action. Second, if a regulatory authority requires a change in a contract, the contract can try to mitigate and allocate the consequences of that change.

### *9.2. Regulatory risk in the DWR contract sample*

Two principal regulatory authorities regulate California's electricity industry: the Federal Energy Regulatory Commission (FERC) at the federal level, and the California Public Utilities Commission (CPUC) at the state level. The FERC has regulatory authority to ensure that wholesale electricity contracts (including the DWR's) are priced in a "just and reasonable" fashion. The CPUC has regulatory authority over retail electricity rates and the investor-owned utilities in California.

Given California's particularly tumultuous recent history, the contracts in the DWR sample may not represent a standard allocation of regulatory risk. Indeed, regulatory challenges to the DWR contracts began shortly after the contracts were signed: for example, the CPUC filed a complaint with FERC, asking the agency to modify or abrogate the DWR contracts.

The DWR contracts contain clauses designed to both prevent regulatory action, and to mitigate and allocate the consequences of a new regulatory requirement. More than half of the DWR's original non-renewable (primarily natural gas) contracts prevent the parties to the contracts from seeking changes in the contracts from a regulatory authority. Approximately half of the DWR contracts also state that the contract price is "just and reasonable" to try to prevent regulatory review. Meanwhile, almost all of the non-renewable contracts designate a course of action that the parties will take if a regulatory agency orders a change in the contract. Specifically, most of the non-renewable contracts specify that if a regulatory authority orders a change in the contract, either the contract price will not change or the parties will use their best efforts to reform the agreement to give effect to the original intention of the parties.

In contrast, none of the renewable contracts attempt to prevent regulatory review, and only two of the seven renewable contracts designate a course of action that will be taken if a regulatory agency orders a change in the contract. Though both renewable and natural-gas contracts presumably face very similar regulatory risks, the treatment of these risks in the renewable contracts is not nearly as formal as in the natural gas contracts. The renewable contracts' lack of attention to regulatory risk may be attributed to either a lack of awareness about the potential risk, or else confidence in the "just and reasonable" nature of the contract terms.

## 10. Conclusions

The DWR's original long-term electricity contracts, upon which our analysis in this paper is based, will help define California's electricity system over the coming

decade. The DWR contracts provide for the construction of a significant number of new natural gas-fired power plants. This may have important implications for the vulnerability of California's economy to natural gas price volatility and possible systematic interruptions in natural gas supply.

Our review of the DWR contracts reveals an obvious conclusion: natural gas-fired and renewable generation technologies have inherently different risk profiles. The allocation of these risks in electricity contracts results in substantially different risk burdens for each party to a contract. Sweeping statements on whether renewable generation is "more risky" or "less risky" than gas-fired generation, however, are simply not possible. Whether a particular generation source is more or less risky depends on the risks being considered, the perceived or actual importance of those different risks, and the risk profile of the rest of the portfolio of resources.

- *Advantages of renewable energy*: What is clear is that renewable energy production does mitigate certain risks relative to natural gas-fired power plants. Specifically, of the risks analyzed in this paper, renewable energy provides the most value relative to natural gas-fired generation by mitigating fuel price and environmental compliance risks. Though fuel price risk can also be managed with fixed-price gas-fired electricity contracts (or financial hedging tools), shifting this risk to the Seller may increase the contract price, and some residual contract default risk will remain for the Buyer. Environmental compliance risks can similarly be allocated to natural gas generators, though our contract sample finds that the allocation of these risks to the Buyer is quite common. As with fuel price risk, shifting the full environmental compliance risk to the Seller may be impossible, and will likely add to the contract price. The use of renewable energy can avoid these costs and risks.
- *Advantages of natural gas*: On the other hand, it is equally clear that gas-fired electricity contracts have certain advantages over renewable energy contracts. In particular, gas-fired generation can provide far better protection against short-term demand risk than can most forms of renewable energy: renewable energy contracts are rarely dispatchable, and renewable electricity is sometimes delivered on an "as-available" basis. The level of demand risk imposed by renewable energy sources depends critically on the type of renewable generation: biomass and geothermal can sometimes offer firm blocks of power, while wind is typically sold on an as-available basis. While renewable energy generators may be able to contract with intermediaries to further "firm-up" their deliveries, this will come at a cost.
- *The gray area*: Renewable and natural gas-fired generation face different challenges with regards to fuel supply risk. Natural gas-fired power plants are more vulnerable to systematic and catastrophic interruptions in fuel supply (affecting many plants simultaneously), while renewable generation is more vulnerable to "normal" hourly, daily, seasonal, and annual variability in fuel supply. Among the different types of renewable generation, the degree of fuel supply risk varies substantially. Prioritizing the relative importance of these different risks is somewhat subjective and will depend on the overall portfolio of fuel supplies that is

used to generate electricity. Our contract sample also suggests that gas-fired generation may perform better in relation to performance risks than renewable electricity; this finding may be limited to the DWR contracts, however, because, in principal, performance risks could be handled equivalently between renewable and natural gas generators. Finally, neither natural gas nor renewables have a clear advantage with regards to regulatory risk.

Although all of the risks discussed in this paper are important, it is sometimes unclear whether regulators, utilities, and other energy purchasers analyze the tradeoffs between all of the various risks. Utilities, for example, appear to place a particular emphasis on demand risk, which favors investment in natural gas-fired generation technologies. Historically, less emphasis seems to have been placed on fuel price and environmental compliance risks, which might otherwise favor renewable technologies. Our hope is that a better understanding of the risks and risk allocation practices associated with different forms of electricity production will help utilities, regulators, and others make more objective investment decisions in the future.

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